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ABSTRACT

Matrix tasks designed to assess the logical properties of multiple classification and multiple seriation were administered to 105 first, third, and fifth grade children. The tasks included cross-class and double series matrices, each of which had a reproduction and a transposition instructional set, and a revised set of cross-class and double series matrix tasks using cylinders and squares. Task presentation order effects and sex differences were not noted. On the traditional matrix tasks, grade level differences reached statistical significance for cross-class tasks only: reproduction of the double series matrix was significantly easier than transposition: no intermatrix reproduction task comparisons were significant, while cross-class transposition was significantly easier than double series transposition. Approximately 50% of the children who passed a cross-class task and failed double series responded with a cross-classification in the traditional blue cylinders format. When stimulus conditions, number of possible correct solutions, and components of visual memory were all held constant on the revised matrix tasks, cross-class was significantly more difficult at the third grade level in both green square and blue cylinder formats. The revised green square and cylinder formats were equally difficult. Accordingly, cross-classification appeared to be more difficult than double seriation for children of transitional status. (Author/RD)

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A STUDY OF CLASSIFYING AND SERIATING MATRICES

by Thomas S. Sipple, Frank H. Hooper,
Spencer S. Swinton, and Rosemarie McMahan

October 1978

Wisconsin Research
and Development Center
for Individualized Schooling

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Report from the Project on
Children's Learning and Development

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Table of Contents

		Page
	Acknowledgments	iv
	List of Tables	vii
	List of Figures	ix
	Abstract	xi
I	Introduction	1
II	Method	13
III	Results	17
IV	Discussion	33
	References	39
	Appendices	43

List of Tables

Table		Page
1	Distribution of Subjects by Grade, Sex, and Age	13
2	Number and Percentage of Subjects Who Passed the Reproduction Subtasks of the Traditional Cross Class and Double Series Matrices	18
3	Number and Percentage of Subjects Who Passed the Transposition Subtasks of the Traditional Cross Class and Double Series Matrices	19
4	Reproduction and Transposition Difficulty Comparisons for the Traditional Matrix Tasks	20
5	Cross Class and Double Series Difficulty Comparisons for the Traditional Matrix Tasks	22
6	Number and Percentage of Passing Subjects Who Exactly Reproduced the Traditional Cross Class and Double Series Matrices	23
7	Number of Subjects Failing to Classify Each Dimension of the Traditional Cross Class Subtasks and Failing to Seriate Each Dimension of the Traditional Double Series Subtasks	25
8	Number of Subjects Who Passed the Traditional Cross Class Reproduction and Transposition Subtasks by Seriating on Brightness of Color Dimension	26
9	Number and Percentage of Subjects Who Passed the Revised Cross Class and Revised Double Series Matrix Tasks Using Green Squares	27
10	Cross Class and Double Series Difficulty Comparisons for the Revised Matrix Tasks Using Green Squares	29
11	Number and Percentage of Subjects Who Passed the Revised Cross Class and Revised Double Series Matrix Tasks Using Blue Cylinders	30
12	Cross Class and Double Series Difficulty Comparisons for the Revised Matrix Tasks Using Blue Cylinders	31

List of Figures

Figure		Page
1	Traditional Cross Class and Double Series Matrix Tasks: Study One	4
2	Traditional Cross Class and Double Series Matrix Tasks: Study Two	6
3	Traditional Cross Class and Double Series Matrix Tasks: Study Three	11

Abstract

Matrix tasks designed to assess the logical properties of multiple classification and multiple seriation were administered to groups of elementary school children. The tasks included cross class and double series matrices (in a "traditional" format) each of which had a reproduction and a transposition instructional set, and a revised set of cross class and double series matrix tasks using cylinders (height x width variation) in one case and squares (area x color density variation) in another. Subjects were 31 first grade children, 42 third grade children, and 32 fifth grade children. While the third graders received all the tasks, the first graders received only the four traditional format tasks and the two revised squares tasks, and the fifth graders received the four revised matrix tasks only. In accord with the results of previous studies it was anticipated that the reproduction tasks should be easier than each of the transposition cases; that while the two reproduction cases (class and series) should be of equivalent difficulty, no predictions were suggested for the transposition cases; and finally, that the revised double series tasks should be of equivalent or lesser difficulty when compared to the revised cross class tasks.

Task presentation order effects and consistent sex differences were absent. Regarding the traditional matrix tasks, grade level differences (Grade 1 vs. Grade 3) were observed for all four tasks but reached statistical significance for cross class tasks only; reproduction of the

double series matrix was significantly easier than transposition; no inter-matrix reproduction task comparisons were significant while cross class transposition was significantly easier than double series transposition. Moreover, approximately 50% of the children who passed a cross class task and failed double series responded with a cross classification in the traditional blue cylinders format. Eighty-five percent of these children passed the double series matrices in the revised formats. Regarding the revised matrix tasks in which stimulus conditions, number of possible correct solutions, and components of visual memory were all held constant, cross class was significantly more difficult at the third grade level in both green square and blue cylinder formats. Further, there were no difficulty differences between the revised green square and revised cylinder formats. Since comparisons between the traditional format matrix tasks are conceptually and methodologically suspect, primary reliance must be placed upon the revised task formats. Accordingly, cross classification appears to be more difficult than double seriation for children of transitional status.

I

The abilities to multiply classes and multiply relations are among the more commonly recognized indicators of concrete operational thought. Matrix formats have been used to investigate cross classification abilities with discrete categories (e.g., Inhelder & Piaget, 1964, pp. 151-195) and double seriation abilities with continuous dimensions (e.g., Bruner & Kenney, 1966, pp. 154-167; Inhelder & Piaget, 1964, pp. 269-274).

Following directly from the fundamental assumption of within-stage correspondence; i.e., the conception of stage as representing a *structure d'ensemble* (Brainerd, 1978; Flavell, 1963, 1970; Hooper, 1973; Hooper, Swinton, & Sipple, 1978; Pinard & Laurendeau, 1969; Wohlwill, 1963, 1973), Piagetian theory predicts a close developmental relationship between multiple class and multiple relations abilities during the concrete operations period. In particular, Piaget has consistently postulated developmental synchrony for performances on measures derived from the class and relational *groupements* (e.g., Inhelder & Piaget, 1964, pp. 278-290; Piaget, 1970a, pp. 723-727; Piaget, 1970b, pp. 24-27 and 65-66; Piaget & Szeminska, 1965, pp. 240-243).

A number of studies have investigated these predictions derived from Piagetian theory. As stated previously,

> In those cases where moderately high degrees of interrelationship were found, as in the multiplicative class and relations tasks used by Lovell, Mitchell, and Everett (1962), Shantz (1967), and Smeds-

> lund (1964) as well as in the original performance similarities reported by Inhelder and Piaget (1964), the inferred ability commonalities may be confounded to an unknown extent by shared method variance (see Shantz, 1967, pp. 133-135). (Hooper, Sipple, Goldman, & Swinton, in press)

Smedslund (1964) found that measures of multiple classification and multiple relationality were approximately of equal difficulty for a sample of 160 children ranging in age from 4 to 11 years. Lagattuta (1970) found that children of age 5-1/2 to 6-1/2 years can successfully deal with a multiple class matrix, while the ability to successfully order a series matrix was not shown by children until 8-1/2 years of age (see also Lagattuta, 1974). Shantz (1967) compared the performances of children 7-1/2, 9-1/2, and 11-1/2 years of age on multiplication of classes (assessed by the Raven Coloured Progressive Matrices Test), multiplication of relations (assessed by using the "diagonals" of 4 x 4 matrices based on various continuous dimensions), and multiplication of infralogical spatial relations (assessed in an adaptation of Piaget's landscape task). Significant rank order correlations between the multiplicative class and relational matrix tasks were found for the two older subsamples. Wong (1975), in a study of children's number concepts at the preschool, kindergarten, and first-grade levels found that multiple classification tasks were significantly more difficult than multiple relations tasks, most notably at the first-grade level. MacKay, Fraser, and Ross (1970), drawing upon the work of Bruner and Kenney (1966) and Inhelder and Piaget (1964), found with samples of children 5 to 8 years of age that reproduction of a double series matrix

was more difficult than reproduction of a cross class matrix which was, in turn, more difficult than a combined class/series case. Their results also showed transposition of the double series matrix to be of greater difficulty than either cross class or class/series. In addition, MacKay et al. (1970) concluded from their data that a matrix composed of discrete categories (i.e., cross class) is no more easily reproduced than it is transposed, while matrices where either or both categories are continuous (i.e., relational) are more easily reproduced than transposed.

In an initial study, Hooper et al. (in press) replicated the MacKay et al. (1970) procedures using a within subjects design.[1] Within a larger sample which also included older elementary school subjects, 160 children (40 from each of 4 levels: preschool, kindergarten, first grade, and second grade) received 6 matrix tasks (reproduction and transposition of double series, cross class, and class series matrices). Preliminary analyses indicated a lack of significant order of presentation effects and a general absence of sex differences. Across the age range there was a significant increase in the proportion of subjects who passed each reproduction and transposition task (see Figure 1), a finding essentially similar to the MacKay et al. (1970) study. Also in agreement with the MacKay et al. (1970) results, transposing the double series matrix

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[1]Stimulus materials consisted of a 3 x 3 matrix board, wooden blocks of three shapes and three colors (cross class), and solid wooden cylinder blocks varying in three values of height and in three values of diameter (double series). In the reproduction subtasks the completed matrix was shown to the subject, the blocks removed by the experimenter, and the subject was asked to replace the blocks so that the array looked the same as it did originally. In the transposition subtasks the completed matrix was again shown to the subject, the blocks removed, the experimenter relocated one of the corner blocks into a different corner, and the subject was asked to replace the blocks so that they made a pattern like they did originally without moving the single replaced block.

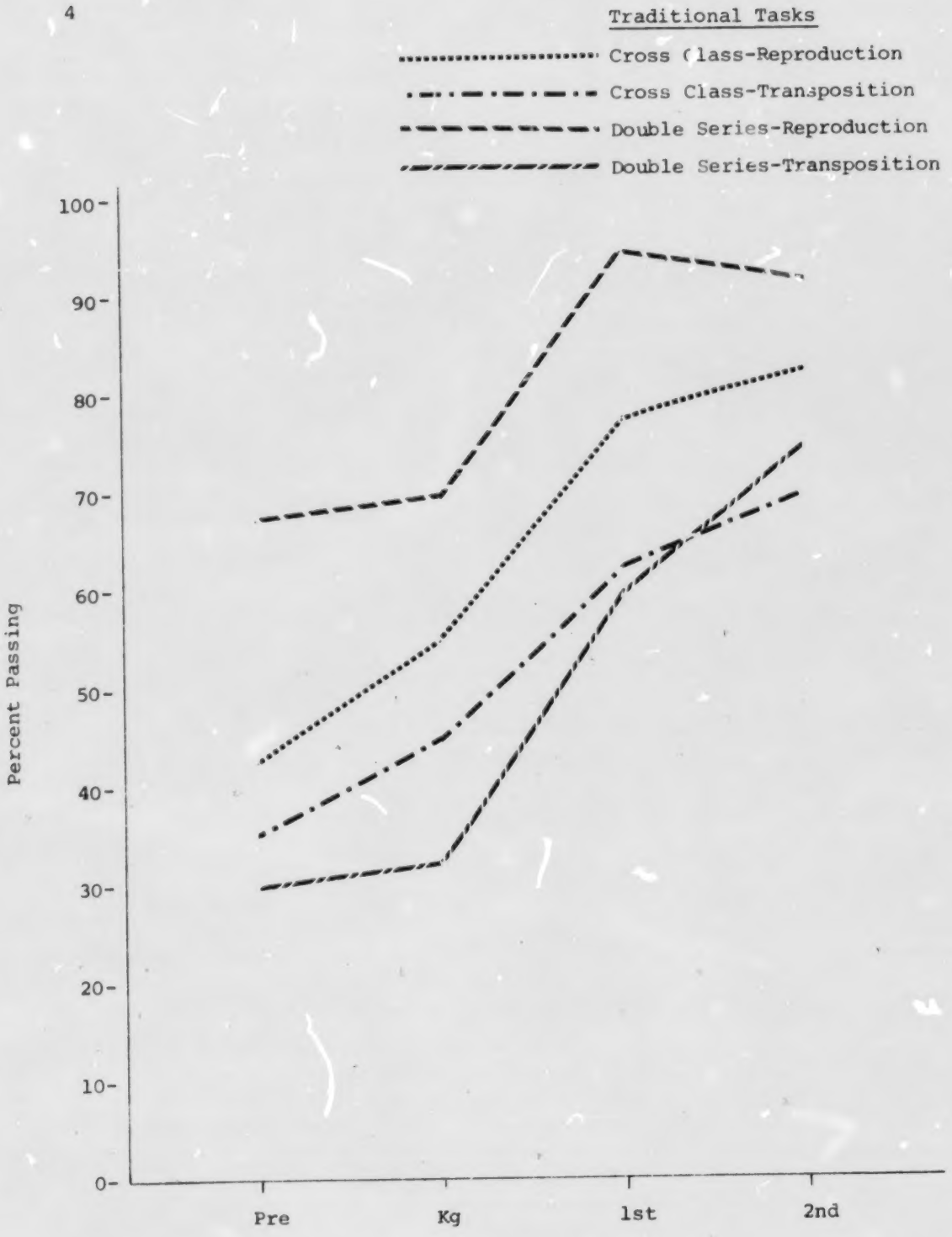

Figure 1. Traditional Cross Class and Double Series Matrix Tasks: Study One

was significantly more difficult than reproducing it ($p < .01$ at each grade and for combined grades). For the cross class matrix, transposition was significantly more difficult than reproduction at first grade and combined grades ($p < .05$). In contrast to one major conclusion of the MacKay et al. (1970) study, reproducing the cross class matrix was significantly more difficult ($p < .05$ for preschool, first grade, and combined grades) than reproducing the double series matrix. No statistically significant differences occurred between transposing the cross class and double series matrices. Responses to the reproduction tasks were examined to find the percentages of passing subjects who reproduced the stimuli in the matrices identical to the presentation arrays. The combined grades percentages of 98 for double series and 79 for cross class closely paralleled the results of MacKay et al. (1970).

In a second study, Hooper and Sipple (1975b) assessed the reliability of the results of study one and the MacKay et al. (1970) results. Forty subjects were drawn from each of the same age/grade levels as study one. The class series task was not used in study two. An additional cross class matrix task was included, but results only from the same cross class and double series tasks used in study one are given below. Study two data showed no significant presentation order or sex effects. As grade level increased, there was a significant increase in the proportion of subjects who passed each reproduction task and also double series transposition (see Figure 2). Transposing the double series matrix was again significantly more difficult than reproducing it ($p < .05$ at combined grades and each grade except preschool), and transposing the cross class matrix was sig-

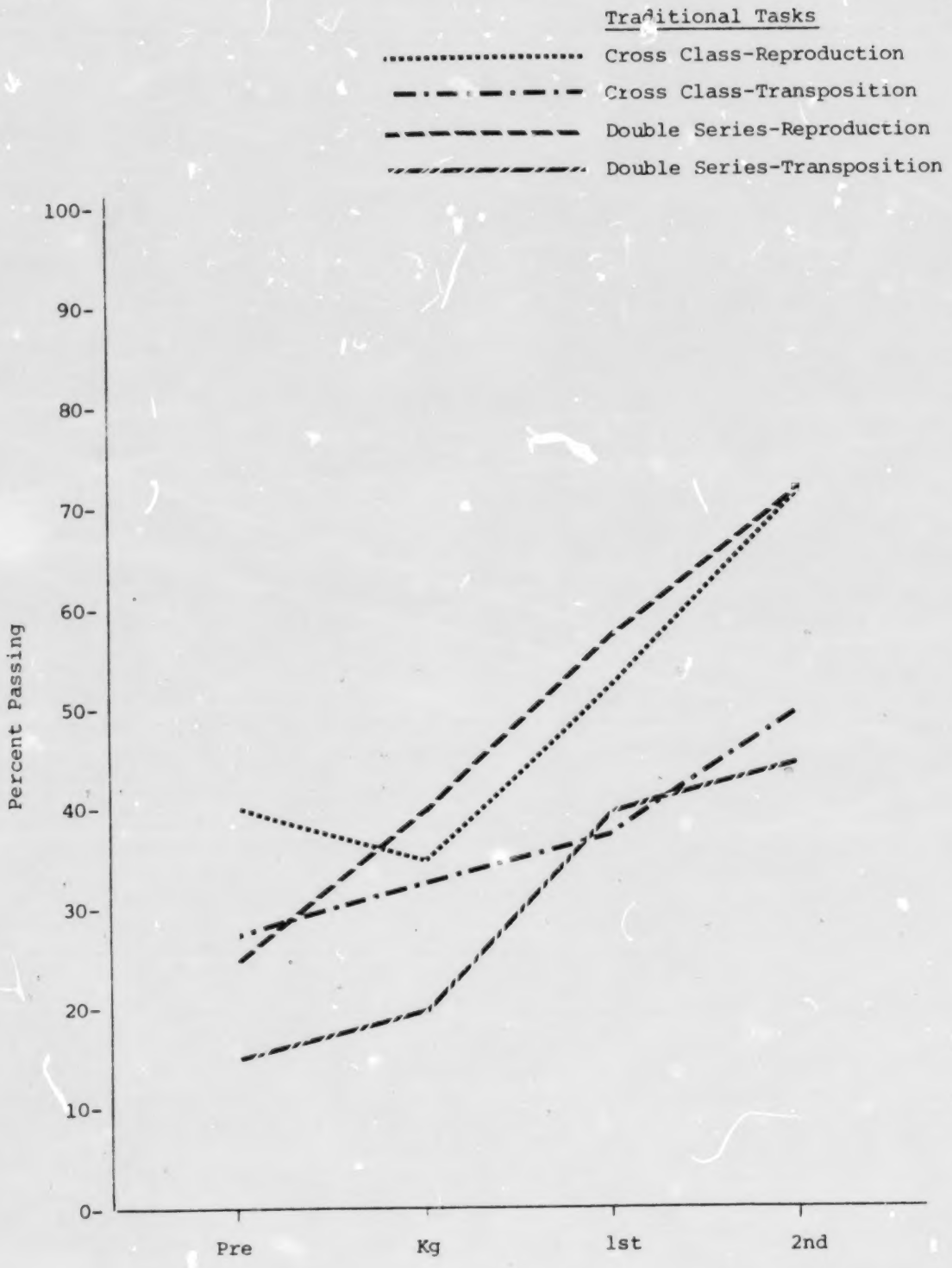

Figure 2. Traditional Cross Class and Double Series Matrix Tasks: Study Two

nificantly more difficult than reproducing it ($p < .05$ at first grade, second grade, and combined grades). In disagreement with study one, there were no significant differences between cross class and double series reproduction cases. As with the study one results, study two showed no significant differences between cross class and double series transposition. Finally, in very close accord with study one, 80% of the subjects in study two reproduced the cross class tasks identically and 100% did the double series case.

From a summary of the results of studies one and two using the transposition tasks in these traditional double series and cross class matrices (see Hooper & Sipple, 1975a), it may be contended that the original structural synchrony conclusions of Inhelder and Piaget (1964) are supported. Critical inspection of these traditional task formats, however, yields serious methodological deficiencies. Task solution requirements and instructional sets should presumably be comparable between the reproduction problems of the series and class cases, as well as between the transposition problems. Any performance differences between the cross class matrix and the double series matrix would be attributable to stimulus array differences stemming from the logical categories at issue, i.e., discrete class exemplars representing class intersections (e.g., red circles) versus ordered items of continuous dimensions. However, this is clearly not the case with these traditional formats. For example, the cross class tasks may be "solved" in a number of ways as long as the shape and color placements are consistent across the three columns and the three rows of the matrix. The essential arbitrariness of the placement order of the class dimensions permits a much greater number of correct patterns than is true for the double

series counterparts. There are 72 correct reproduction patterns for cross class but only 8 for double series; and 8 correct transpositions for cross class while only 2 for double series. (Note: The block replaced by E in the transposition cases reduces the number of possible solutions.)

Other deficiencies concern the confounding variables of visual memory in the reproduction cases, and the component of spatial ability, i.e., the ability to rotate a visual image in short-term memory, in the transposition cases. With these traditional matrix formats there exist correct responses that are identical to the original presentation and others that are reflections or rotations of it. These solutions do not provide unequivocal evidence that the subject has the multiplicative abilities in question.

The present authors developed a revised format of double series and cross class matrix tasks. In this revised format the same cylinders used in the traditional double series task can be used, but are presented to the subject in a cross classified fashion such that height is constant within each row of the 3 x 3 matrix and diameter is held constant within each column, yet neither dimension is seriated across the rows or columns (see Table A.1, p. 45). The cylinders are removed, and the experimenter replaces one (specifically, the tallest, widest block) that had occupied a corner position to the center of the matrix. There are eight possible correct solutions to this revised cross class task, none of which can be the original stimulus array nor reflections or rotations of it (see Tables A.1 and A.2). Note also that none can be a seriated matrix. The revised double series task involves the identical materials and procedures except that the experimenter places the cylinder of intermediate height and intermediate width in the center posi-

tion of the matrix, thus forcing all eight possible correct solutions to be double seriations. As with the revised cross class task, none of the correct responses to the revised double series matrix have been shown to the subject and none are reflections or rotations of the original array (see Tables A.1 and A.3). If the revised double series task is easier to solve than the revised cross class task, it can be so only because of the perceptual cue of serial order. Logically, it is clear that the revised cross class task cannot be easier to solve than revised double series. In accord with the orthodox Piagetian prediction, subjects who determine the relationship between the nine stimuli when first presented, classify the matrix in the revised cross class format, logically can seriate the matrix in the revised double series format. That is, when stimulus materials, number of correct solutions, components of visual memory and spatial ability are held constant across the series and class matrices, the question of relative difficulty yields only two possible answers: (a) either double seriation is no different than any other cross classification, or (b) the additional perceptual cue of seriated values will enhance performance on the double series task. Empirical cases of double series being more difficult than cross class in these revised formats can occur only through errors of measurement.

In study three (Sipple & Hooper, 1976) 40 Ss from each preschool, kindergarten, first, and second grades were assessed. Each child received the four traditional matrix tasks (reproduction and transposition of cross class and of double series) and two revised tasks (cross class and double series) in one of two orders of presentation. Results showed no significant

presentation order effects or sex differences. There was a significant positive relationship between age-grade level and the proportion of subjects passing each traditional task (see Figure 3) and the revised double series task. Significantly superior performances on the reproduction when compared to the transposition task were shown for the traditional double series task only ($p < .05$ at first, second, and combined grades). None of the between matrix reproduction comparisons were significant and no consistent pattern was shown across grades. For the transposition comparisons, however, double series was of greater difficulty than cross class at each grade and statistically significant ($p < .01$) in all cases except kindergarten and first grade. In contrast, performances on the revised tasks showed cross class to be of greater difficulty than double series at each first, second, and combined grades. This difference was significant ($p < .05$) for second grade and combined grades.

While the results of investigations using the traditional tasks only can deal with relative task difficulties, the differing solution requirements between these measures do not permit discussion of potential developmental synchrony or asynchrony of the multiple class and multiple series abilities. The possible influences of visual memory within the formats also make suspect inferences that a subject has either logical ability, or assuming the subject has, to what extent it is what is being measured.

Direct comparisons of the ability to multiply classes with the ability to multiply relations were undertaken in study three by using revised matrix tasks such that performance demands other than demands stemming from the logical categories were equated. Even though our prediction that multiple class understanding does not precede multiple series understanding is

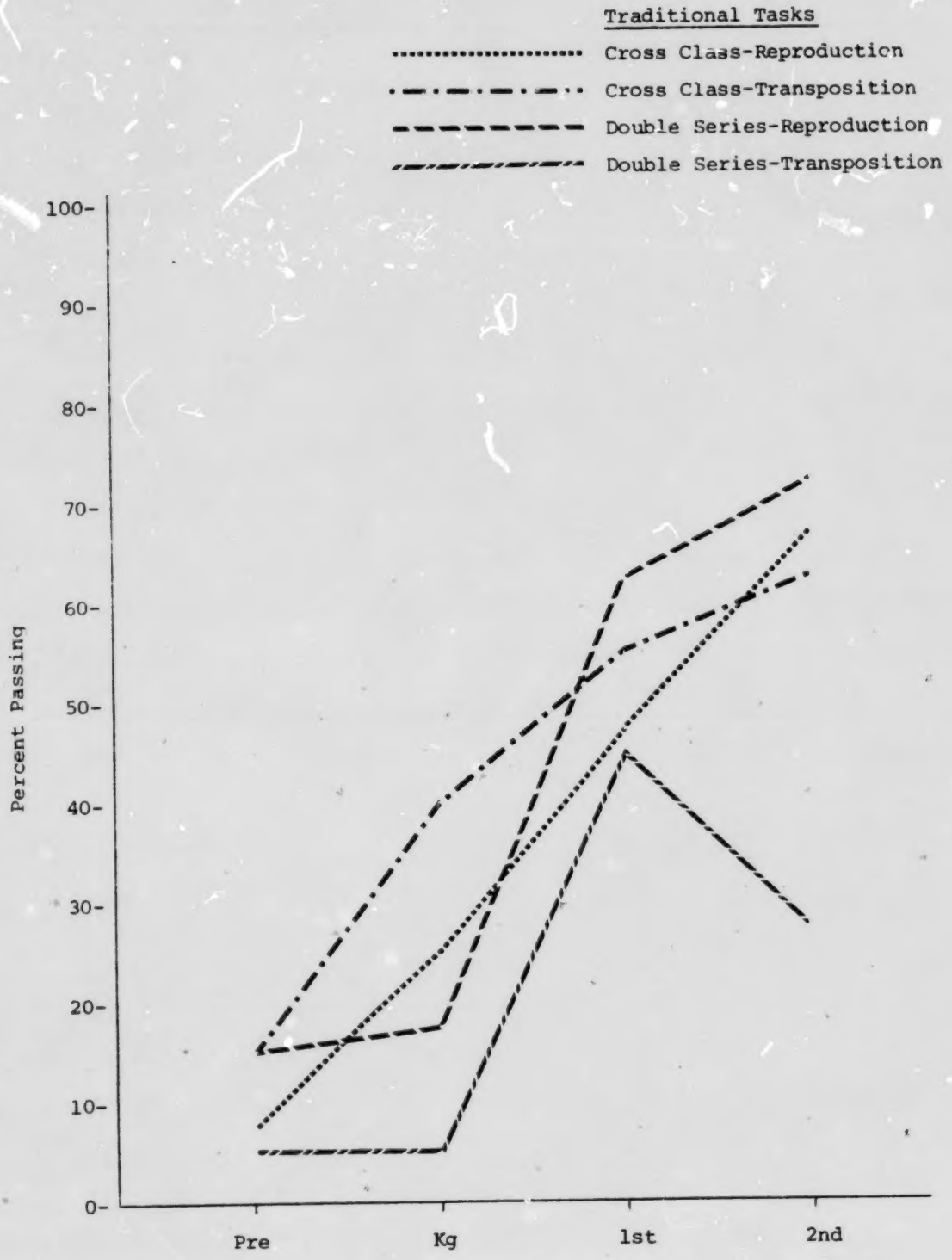

Figure 3. Traditional Cross Class and Double Series Matrix Tasks: Study Three

given some support by the data, the notably low performances on both revised tasks do not provide sufficient statistical variance at three of the four assessed grade levels. By increasing the age of the subject sample (e.g., 8 to 12 years) and using materials in the matrices which may present less difficulty to the subjects (e.g., stimuli varying in density of a single color along one dimension and in three values of area along the other), it was expected that passing percentages would increase to a level making statistical comparisons more meaningful. Modifying the materials of the revised tasks but using the same procedures is intended only to reduce equally the surface difficulty of the two tasks. Differences in difficulty between them should arise only from the differing logical demands. The study to be reported in the remainder of this report, the fourth in the series, sought to disentangle the logical and performance task demands with older children using the revised tasks in addition to a final replication using the traditional tasks.

II

Method

Subjects

Subjects for the study were first, third, and fifth grade children from the Madison, Wisconsin school district. Distribution of the subject sample by age and sex is given in Table 1.

Materials

Each matrix was arranged on a square wooden board sectioned into nine (3 x 3) individual squares each 110 x 110 mm.

Traditional cross class matrix. Stimuli were three square wooden blocks, three circle blocks, and three triangle blocks. One block of each shape was red, one was yellow, and one was blue. Each block has a circumference of 204 mm and a thickness of 10 mm. The blocks were arrayed on the color and shape dimensions.

Traditional double series matrix. Stimuli were nine cylindrical wooden blocks; three were 100 mm high, three were 75 mm high, and three were 50 mm high. One block of each height had a diameter of 100 mm, one was 65 mm in diameter, and one was 35 mm in diameter. All the cylinders were blue. The blocks were arrayed on the width and height dimensions.

Table 1

Distribution of Subjects by Grade, Sex, and Age

Grade	Subjects	Males	Females	Mean Age	Range
1	31	14	17	6-9	6-3 to 7-4
3	42	17	25	8-10	8-3 to 9-10
5	32	16	16	10-8	9-9 to 11-7

Revised cross class matrix using green squares. Stimuli were nine square wooden blocks; three were 52 mm x 52 mm x 6 mm, three were 38 mm x 38 mm x 6 mm, and three were 25 mm x 25 mm x 6 mm. One block of each size was dark green, one was medium green, and one was light green. The stimuli were located on the board such that within each column size was constant and within each row density of color was constant. However, neither dimension was seriated across the columns or rows of the matrix.

Revised double series matrix using green squares. The same square blocks were used as above.

Revised cross class matrix using blue cylinders. Cylinders used were the same as those for the traditional double series matrix. The stimuli were located such that within each row height was constant and within each column diameter was constant. However, neither dimension was seriated across the rows or columns of the matrix.

Revised double series matrix using blue cylinders. Cylinders were identical to those of the revised cross class matrix.

Procedure

Four traditional matrix tasks and four other matrix tasks developed by the authors were used to assess the development of the abilities of multiple classification and multiple seriation. For each traditional reproduction task, E removed all the blocks from the matrix, and S was asked to put them back so the board looked "just the same as it did before" E removed them. With each traditional transposition task, E removed all the blocks from the matrix and then placed the block that had originally occupied the lower left-hand position (of the S) in the upper left-hand

position. S was then asked to place the blocks on the board so they made a "pattern like they did before." (Appendix B presents the complete procedures for administering the traditional matrix tasks.) The complete administration procedures for the revised tasks are given in Appendix C.

In order to pass the traditional cross class reproduction task, a subject was required to classify the color dimension in one direction and the shape dimension in the perpendicular direction. In order to pass the traditional double series reproduction task, a subject was required to seriate height and width in perpendicular directions. In order to pass each transposition task of the traditional matrices, a subject was required to fulfill the same criteria as the traditional reproduction cases without moving the replaced block. In order to pass the revised cross class task using green squares, a subject was required to classify size in one direction and density of color in the perpendicular direction without moving the block replaced to the center. In order to pass the revised double series task using blue cylinders, a subject was required to seriate the height and width dimensions in perpendicular directions without moving the block replaced to the center. (The criteria for the revised cross class task using blue cylinders and the revised double series task using green squares were the same as above except for the different dimensions.)

The first grade Ss were administered the two traditional matrix tasks and the two revised tasks using green squares. The same tasks as well as the two revised tasks using blue cylinders were given to the third graders, and the fifth grade Ss received all but the traditional tasks.

The tasks were administered to the first grade Ss in one of four counterbalanced orders: (1) revised cross class using green squares (a), revised double series using green squares (b), traditional cross class (c), traditional double series (d); (2) badc; (3) cdba; (4) dcab. Third grade Ss received the tasks in one of four counterbalanced orders: (1) a, b, c, d, revised cross class using blue cylinders (e), revised double series using blue cylinders (f); (2) badcfe; (3) cdbaef; (4) dcabfe. Fifth grade Ss were administered the matrices in one of two counterbalanced orders: (1) abef; and (2) bafe.

III

Results

Initial considerations include possible order of task presentation and sex difference effects on matrix task performances. Results of chi-square tests at each grade and for combined grades showed an absence of significant performance differences on each of the traditional and revised tasks due to presentation order. Comparisons of the frequencies of male versus female subjects passing the traditional matrix tasks were nonsignificant in all cases with the reproduction tasks, and significant with the transposition tasks in two cases only. At third grade and for combined grades the proportion of males passing double series transposition was significantly greater than for females ($\chi^2 = 6.09$, $df = 1$, $p < .05$, Grade 3; $\chi^2 = 7.85$, $df = 1$, $p < .01$, combined grades). No sex differences of statistical significance were found with either of the two revised tasks using green squares or the two revised tasks using the blue cylinders.

Performances on the Traditional Matrix Tasks

The frequencies and percentages of subjects who passed the reproduction and the transposition tasks of the traditional cross class and double series matrices are given in Tables 2 and 3. As anticipated, the percentage passing at Grade 3 was higher than at Grade 1 for each of the four tasks. However, the differences were statistically significant only for the cross class tasks (reproduction: χ^2 3.89, $df = 1$, $p < .05$; transposition: $\chi^2 = 6.22$, $df = 1$, $p < .01$).

The difficulties of the traditional reproduction compared with transposition tasks are presented in Table 4. At each grade transposition of

Table 2

Number and Percentage of Subjects Who Passed the Reproduction Subtasks of the Traditional Cross Class and Double Series Matrices

Grade	Cross Class		Double Series	
	Number Passed	Percent	Number Passed	Percent
1				
Males (n=14)	10	71.4	12	85.7
Females (n=17)	15	88.2	15	88.2
Total (n=31)	25	80.6	27	87.1
3				
Males (n=17)	16	94.1	16	94.1
Females (n=25)	24	96.0	25	100.0
Total (n=42)	40	95.2	41	97.6
Combined				
Males (n=31)	26	83.9	28	90.3
Females (n=42)	39	92.9	40	95.2
Total (n=73)	65	89.0	68	93.2

Table 3

Number and Percentage of Subjects Who Passed the Transposition Subtasks of the Traditional Cross Class and Double Series Matrices

Grade	Cross Class		Double Series	
	Number Passed	Percent	Number Passed	Percent
1				
Males (n=14)	8	57.1	10	71.4
Females (n=17)	14	82.4	7	41.2
Total (n=31)	22	71.0	17	54.8
3				
Males (n=17)	17	100.0	16	94.1
Females (n=25)	22	88.0	15	60.0
Total (n=42)	39	92.9	31	73.8
Combined				
Males (n=31)	25	80.6	26	83.9
Females (n=42)	36	85.7	22	52.4
Total (n=73)	61	83.6	48	65.8

Table 4

Reproduction and Transposition Difficulty Comparisons

for the Traditional Matrix Tasks

		CCT			DST		
		+	-		+	-	
First Grade	+	20	5	+	16	11[a]	
	CCR			DSR			
	-	2	4	-	1	3	
Third Grade	+	37	3	+	31	10[a]	
	CCR			DSR			
	-	2	0	-	0	1	
Combined Grades	+	57	8	+	47	21[a]	
	CCR			DSR			
	-	4	4	-	1	4	

[a] $p < .01$

Note: The upper-left (++) quadrant of each comparison gives the number of subjects passing both tasks; the upper-right (+-) quadrant, the number passing the reproduction (R) task and failing the transposition (T) task; the lower-left (-+), failing reproduction and passing transposition; and the lower-right (--), failing both.

the cross class matrix was more difficult than reproduction, but none of the differences were statistically significant. Transposing the double series matrix, however, was significantly more difficult ($p < .01$) than reproducing it at each grade and for combined grades. The significant sex difference on the percent passing double series transposition at third grade and for combined grades was noted earlier. All 10 third graders who passed double series reproduction but failed transposition were female. Only 3 of the 21 Ss from both grades who followed this pattern were male.

The inter-matrix task comparisons were evaluated with the McNemar Test for the Significance of Change. There were no significant differences in difficulty between cross class and double series reproduction (see Table 5). Comparisons of the transposition tasks, however, showed double series to be of greater difficulty than cross class. This pattern occurred at each grade and reached statistical significance at third grade ($p < .01$) and when combining the two grades ($p < .05$). (Fifteen of the 18 Ss who passed the cross class task but failed double series were female, and seven of them were third graders.) In further considering these comparisons, the protocols of the Ss who passed cross class but failed double series were examined. Two of the four Ss from first and third grades failed reproducing the double series task by producing a cross classified array of the blue cylinders. In the same grades, 10 of the 18 Ss correctly cross classified the blue cylinders in the seriation transposition format.

Table 6 presents the frequencies of subjects who passed the reproduction tasks of the traditional cross class and double series cases by replacing the stimuli identical to the presentation arrays. From 64 to 100%

Table 5

Cross Class and Double Series Difficulty Comparisons

for the Traditional Matrix Tasks

		CCR			CCT		
		+	-		+	-	
First Grade	DSR +	22	5	DST +	12	5	
	DSR -	3	1	DST -	10	4	
Third Grade	DSR +	39	2	DST +	31	0	[a]
	DSR -	1	0	DST -	8	3	
Combined Grades	DSR +	61	7	DST +	43	5	[b]
	DSR -	4	1	DST -	18	7	

[a] $p < .01$

[b] $p < .05$

Table 6

Number and Percentage of Passing Subjects Who Exactly Reproduced the Traditional Cross Class and Double Series Matrices

	Cross Class			Double Series		
	Number Passed	Exactly Reproduced		Number Passed	Exactly Reproduced	
Grade		Number	Percent of Passing		Number	Percent of Passing
1	25	16	64.0	27	27	100.0
3	40	34	85.0	41	40	97.6
Combined	65	50	76.9	68	67	98.5

of the correct reproductions were the original array shown by the E. In addition, a greater percentage of these exact reproductions was found with the double series matrix than with the cross class matrix. These patterns are in essential accord with the earlier studies of MacKay et al. (1970), Hooper et al. (in press), Hooper and Sipple (1975b), and Sipple and Hooper (1976).

Table 7 presents the number of subjects committing placement errors according to the dimensions in question for each matrix type. No predominant error category was consistently observed for any traditional task.

An additional consideration is the possibility that subjects who pass the traditional cross class task do so by seriating the color brightness dimension, i.e., yellow, red, blue. As Table 8 indicates, there was no tendency for subjects to do so; i.e., none of the successful reproduction cases and only 26.2% of the successful transposition cases produced a rank-ordered brightness array.

Performances on the Revised Matrix Tasks Using Green Squares

The numbers and percentages of subjects who passed the revised tasks using green squares are given in Table 9. The proportion of subjects who passed the cross class measure did not significantly increase as grade level increased. The proportion of subjects who passed the double series measure, however, did differ significantly with grade ($\chi^2 = 10.92$, $df = 3$, $p < .05$). The marked increase here occurred between first and third grades. An unexpected, although statistically nonsignificant, decrease from Grade 3 to Grade 5 was also found.

Table 7

Number of Subjects Failing to Classify Each Dimension of the Traditional Cross Class Subtasks and Failing to Seriate Each Dimension of the Traditional Double Series Subtasks

	Cross Class				Double Series			
	Reproduction		Transposition		Reproduction		Transposition	
Grade	Color	Shape	Color	Shape	Width	Height	Width	Height
1	5	2	4	6	3	3	7	10
3	1	1	2	2	1	0	7	6
Combined	6	3	6	8	4	3	14	16

Table 8

Number of Subjects Who Passed the Traditional Cross Class Reproduction and Transposition Subtasks by Seriating on Brightness of Color Dimension

	Reproduction		Transposition	
Grade	Number Passed	Number Passed With Seriating	Number Passed	Number Passed With Seriating
1	25	0	22	6
3	40	0	39	10
Combined	65	0	61	16

Table 9

Number and Percentage of Subjects Who Passed the Revised Cross Class and Revised Double Series Matrix Tasks Using Green Squares

Grade	Cross Class		Double Series	
	Number Passed	Percent	Number Passed	Percent
1				
Males (n=14)	7	50.0	5	35.7
Females (n=17)	9	52.9	10	58.8
Total (n=31)	16	51.6	15	48.4
3				
Males (n=17)	9	52.9	14	82.4
Females (n=25)	16	64.0	21	84.0
Total (n=42)	25	59.5	35	83.3
5				
Males (n=16)	10	62.5	13	81.3
Females (n=16)	14	87.5	11	68.8
Total (n=32)	24	75.0	24	75.0
Combined				
Males (n=47)	26	55.3	32	68.1
Females (n=58)	39	67.2	42	72.4
Total (n=105)	65	61.9	74	70.5

Table 10 shows that cross class was more difficult than double series in the revised green square format. The differences were significant at third grade ($p < .01$), and for combined grades ($p < .05$). There were only five subjects (three in first grade and two in fifth grade) who passed the cross class task and failed the double series task (see the lower-left quadrants in Table 10).

Performance on the Revised Matrix Tasks Using Blue Cylinders

The numbers and percentages of subjects who passed the revised tasks using blue cylinders are given in Table 11. From third grade to fifth grade the proportion passing either cross class or double series did not significantly increase. In contrast, the percentage who passed the double series task decreased from Grade 3 to 5, although not statistically significant, as it did on the green square double series task.

Table 12 shows the relative difficulty of the revised blue cylinder tasks. As with the green square task, double series was significantly easier at third grade ($p < .05$) and contributed largely to the significant difference for combined grades ($p < .01$). Also, at fifth grade no subjects failed double series and passed cross class, although three subjects did the converse.

Table 10

Cross Class and Double Series Difficulty Comparisons for the Revised Matrix Tasks Using Green Squares

		CC +	CC -
First Grade	DS +	13	2
	DS -	3	13

		CC +	CC -
Third Grade	DS +	25	10[a]
	DS -	0	7

		CC +	CC -
Fifth Grade	DS +	22	2
	DS -	2	6

		CC +	CC -
Combined Grades	DS +	60	14 [b]
	DS -	5	26

[a] $p < .01$

[b] $p < .05$

Table 11

Number and Percentage of Subjects Who Passed the Revised Cross Class and Revised Double Series Matrix Tasks Using Blue Cylinders

Grade	Cross Class		Double Series	
	Number Passed	Percent	Number Passed	Percent
3				
Males (n=17)	7	41.2	15	88.2
Females (n=25)	17	68.0	19	76.0
Total (n=42)	24	57.1	34	81.0
5				
Males (n=16)	10	62.5	12	75.0
Females (n=16)	10	62.5	11	68.8
Total (n=32)	20	62.5	23	71.9
Combined				
Males (33)	17	51.5	27	81.8
Females (n=41)	27	65.9	30	73.2
Total (n=74)	44	59.5	57	77.0

Table 12

Cross Class and Double Series Difficulty Comparisons for the Revised Matrix Tasks Using Blue Cylinders

		CC +	CC −	
Third Grade	DS +	20	14	a
	DS −	4	4	

		CC +	CC −	
Fifth Grade	DS +	20	3	
	DS −	0	9	

		CC +	CC −	
Combined Grades	DS +	40	17	b
	DS −	4	13	

[a] $p < .05$

[b] $p < .01$

IV

Discussion

Classification and seriation skills have been studied by experimenters interested in the development of number concepts. Theoretical and empirical claims of synchrony in the development of these two skills and claims of sequence have also been posited. Essentially nonverbal tasks have been designed for use with children of preoperational and concrete operations stage ages. Task analysis led us to see that demands on skills other than multiple seriation and classification are made by the matrix formats used earlier by Bruner and Kenney (1966), Inhelder and Piaget (1964), and MacKay et al. (1970), and that these demands varied between tasks. Some varying properties between the tasks were obvious (i.e., stimuli) and others revealed (i.e., number of alternative correct solutions). These earlier tasks (i.e., those we have called traditional matrix tasks) and others we have developed (i.e., the revised tasks) were used in this study. The traditional tasks were used in order to obtain further normative data for comparison with previous studies. Convincing empirical support showing any pattern of difficulty to suggest a sequence of acquisition requires responses to tasks that differ only in their demands on the abilities in question. For this reason the revised tasks were used.

In all except two grade comparisons, performance on all eight matrix tasks increased with increasing grade level. This improvement was statis-

tically significant for three of the measures: traditional cross class reproduction and transposition, and revised double series with green squares. Performances of first and third grade Ss on the two traditional cross class tasks exceeded those of the same grade levels of the previous studies of Hooper and Sipple (1975b), Hooper et al. (in press), and Sipple and Hooper (1976). The percentages of subjects passing the traditional double series tasks were also greater than for the samples of Hooper and Sipple (1975b) and Sipple and Hooper (1976), but less than that found in Hooper et al. (in press). As a possible accounting for this, the mean ages of the first and third grade Ss in the Hooper et al. (in press) study were from 5 to 6 months greater than in this study.

Although not statistically significant, the traditional cross class transposition task was more difficult than the counterpart reproduction task. This direction of difficulty agrees with the Hooper and Sipple (1975b), Hooper et al. (in press), and MacKay et al. (1970) results, but is in contrast to the data of Sipple and Hooper (1976). These four earlier studies showed that reproduction of the traditional double series matrix was less difficult than transposition. The present data also support this difference with statistical significance at each grade.

The difficulties of the two traditional reproduction tasks showed no significant differences in the present results. This agrees with the results of Hooper and Sipple (1975b) and Sipple and Hooper (1976), but does not conform to the Hooper et al. (in press) and MacKay et al. (1970) studies. In the Hooper et al. (in press) data cross class was more difficult than double series, while for MacKay et al. (1970) double series was more difficult. In contrast to the studies of Hooper and Sipple (1975b) and Hooper

et al. (in press), but in agreement with MacKay et al. (1970) and Sipple and Hooper (1976), transposition was more difficult with the double series task than with the cross class task.

It was stated that between 50 and 56% of the Ss in this sample who passed a traditional cross class task and failed the double series counterpart actually failed the latter by cross classifying the blue cylinders. These alternate solutions may not necessarily indicate that the Ss could not double seriate. In fact, further examination showed that more than 85% of these Ss passed the double series matrices in the revised formats. These "incorrect" responses with the traditional double series matrix merely suggest that the seriated values of the stimuli did not serve as sufficient perceptual cues for the Ss to *choose* to seriate.

The unique properties of the seriated matrix were lost by a S exchanging either two of its columns or two of its rows (or both). If the same exchanges are made with the traditional cross class case, the matrix remains classified. As stated previously, because exchanges are allowed with the traditional cross class matrix, there are 72 different reproductions of it that are correct, but only 8 for double series; there are 8 transpositions of cross class that are correct and 2 for double series.

The revised matrices using blue cylinders and green squares were developed to assess the two multiplicative abilities. Unlike the traditional tasks, stimulus materials, number of correct solutions, and components of visual memory are held constant between the series and class tasks of each revised task. In a previous study with children from preschool through second grade, between 2.5% and 17.5% of the Ss passed

the revised blue cylinder tasks (Sipple and Hooper, 1976). These previous results made tenuous any comparisons of double series with cross class. It was expected, however, that children of higher grades would show more performance variance on the blue cylinder tasks. In the present study, third and fifth grade children, ranging in age from 8-1/4 years to 11-1/2 years, were administered the revised matrices using blue cylinders. Also, on the assumption that the cylinders varying on the dimensions of height and diameter may present more difficulty to young subjects than would thin squares varying in size and density of color, we decided to include a version of the revised tasks using stimuli with these latter properties. First, third, and fifth grade children were given the revised tasks using green squares. Examination of the percents passing (from Tables 9 and 11) and of the pass/fail patterns showed no significant differences between children's performances on the revised blue cylinder versus green square tasks, i.e., for combined Grades 3 and 5 class and series cases there were 23 Ss who failed blue cylinders and passed green squares and 16 Ss who did the converse.

Data combined from the two grades assessed with the blue cylinder tasks and the three grades given the green square tasks showed double series to be significantly easier than cross class. Essentially, this difference was due to the contribution of the third grade results. At first grade and fifth grade, between 84 and 91% of the Ss either passed or failed both the series and class tasks of each revised measure, preventing comparisons of the development of the two abilities. At third grade, between 57 and 76% of the Ss either passed or failed both tasks of each revised measure, providing data which made statistical comparisons more meaningful.

The notion that double series skills precede cross class skills was supported by data from 78% of the third grade Ss (14/18) who failed only one of the two revised blue cylinder tasks. Further examination showed that of the remaining four Ss, all passed double series with green squares but two failed cross class. With regard to possible measurement error, it is noted that all (10) Ss in the third grade who failed only one of the two green square tasks showed double series to be easier; therefore, no Ss showed double series to be more difficult than cross class across both stimulus sets. Two of those 10 third graders demonstrated the reverse sequence in their performances on the blue cylinder tasks. For 5 of the remaining 8 third graders double series was easier than cross class across both stimulus sets.

Given the notable lack of rigor in methodologies using the so-called "traditional" tasks only, conclusions concerning children's multiple classification and relational abilities are of dubious logical and development validity. Nonetheless, the series of four Wisconsin studies suggest that (a) reproducing a matrix is easier than transposing it (particularly, for the double series matrix), (b) there is little difference in difficulty between reproducing the classified matrix and the seriated matrix, and (c) the relative difficulty of transposing multiple class and multiple series remains equivocal.

Of greater importance, to compare the difficulty of multiplying series and multiplying classes in the revised task formats, the ages from about 8 to 10 years in the present study were critical. For the grade levels outside this range, double seriation proved to be no different in difficulty

than cross classification. However, for from 1/4 to 1/3 of the third grade Ss, we conclude that the additional perceptual cue of seriated values significantly enhanced performance on double series.

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Appendix A

STIMULUS ARRAYS AND CORRECT SOLUTIONS FOR
THE REVISED MATRIX TASKS

Table A.1

Original Stimulus Array for Revised Cross Class Task
and Revised Double Series Task

S

F-2	S-2	M-2
F-1	S-1	M-1
F-3	S-3	M-3

E

Key: S = skinny, M = medium width, F = fat;
1 = short, 2 = medium height, 3 = tall

Table A.2

Display of All (8) Possible Correct Solutions to
Revised Cross Class Task

S

S-1	F-1	M-1
S-3	F-3	M-3
S-2	F-2	M-2

E

S

S-2	F-2	M-2
S-3	F-3	M-3
S-1	F-1	M-1

E

S

M-1	F-1	S-1
M-3	F-3	S-3
M-2	F-2	S-2

E

S

M-2	F-2	S-2
M-3	F-3	S-3
M-1	F-1	S-1

E

S

S-2	S-3	S-1
F-2	F-3	F-1
M-2	M-3	M-1

E

S

S-1	S-3	S-2
F-1	F-3	F-2
M-1	M-3	M-2

E

S

M-2	M-3	M-1
F-2	F-3	F-1
S-2	S-3	S-1

E

S

M-1	M-3	M-2
F-1	F-3	F-2
S-1	S-3	S-2

E

Key: S = skinny, M = medium width, F = fat;
1 = short, 2 = medium height, 3 = tall

Table A.3

Display of All (8) Possible Correct Solutions
to Revised Double Series Task

S

S-1	M-1	F-1
S-2	M-2	F-2
S-3	M-3	F-3

E

S

S-3	M-3	F-3
S-2	M-2	F-2
S-1	M-1	F-1

E

S

F-1	M-1	S-1
F-2	M-2	S-2
F-3	M-3	S-3

E

S

F-3	M-3	S-3
F-2	M-2	S-2
F-1	M-1	S-1

E

S

S-3	S-2	S-1
M-3	M-2	M-1
F-3	F-2	F-1

E

S

S-1	S-2	S-3
M-1	M-2	M-3
F-1	F-2	F-3

E

S

F-3	F-2	F-1
M-3	M-2	M-1
S-3	S-2	S-1

E

S

F-1	F-2	F-3
M-1	M-2	M-3
S-1	S-2	S-3

E

Key: S = skinny, M = medium width, F = fat;
1 = short, 2 = medium height, 3 = tall

Appendix B

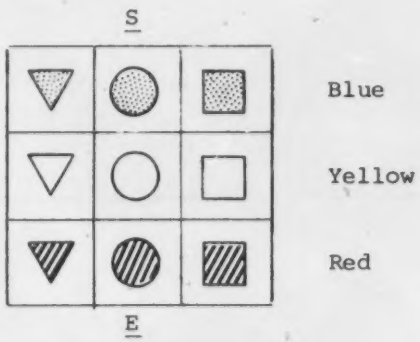
ADMINISTRATOR'S MANUAL FOR TRADITIONAL CROSS CLASS
AND TRADITIONAL DOUBLE SERIES MATRIX TASKS

Traditional Cross Classification Matrix

Warm-up

E places the nine blocks in a random fashion on the table next to the matrix board and says, "Tell me what you see here." If S does not mention the attributes, "triangle," "circle," "square," E asks what shapes S sees. Also, if S does not mention the attributes "red," "yellow," "blue," E asks what colors S sees.

E then says, "Now I am going to put the blocks on here in a special way." E places the blocks on the board saying, "Look very carefully at how the blocks go."



Replacement

E says, "Now I am going to take away one block and I want you to put it back so that the board looks just the same as it does right now." E then removes ▽, puts it on the table near the Ss left hand, and says, "Now you put this block back where it belongs." When S has finished, E says, "Now I am going to take away two blocks and I want you to put them back so the board looks just the same as it does right now." E then removes ▨ and ◯, places them in front of S, and says, "Now you put

these back where they belong." When S has finished, E says, "Now I am going to take away three blocks and I want you to put them back so the board looks just the same as it does right now." E then removes , , , places them in front of S and says, "Now you put these back where they belong."

Reproduction

E says, "This time I am going to take all of the blocks off the board and I want you to put them back so the board looks just the same as it does right now. Look at the board very carefully so you can remember just what it looks like." When S has finished looking, E removes (unsystematically) the nine blocks, mixes them on the table, and says, "Now I want you to put the blocks back so that the board looks just the same as it did before."

Transposition

E says, "This time I am going to take all of the blocks off the board again. Then I am going to put one back, but it will be in a different place. I want you to put the blocks back so they make a pattern like this one. Now look at the board again very carefully so you can remember just what it looks like." When S has finished looking, E removes (unsystematically) the nine blocks, mixes them on the table, and places the bottom left hand block (blue square) at the top left-hand corner. E then says, "Now you put all these blocks back on the board so they make a pattern like they did before. Remember, this one (pointing at blue square) must stay right here."

Traditional Double Seriation Matrix

Warm-up

E places the nine blocks in a random fashion on the table next to the matrix board and says, "Tell me what you see here." If S does not mention the different heights, E points to blocks differing in height (but not width) and asks how they are different. Also, if S does not mention the different widths, E points to blocks differing in width (but not height), and asks how they are different.

E then says, "Now I am going to put the blocks on here in a special way." E places the blocks on the board saying, "Look very carefully at how the blocks go."

S

S-1	M-1	F-1
S-2	M-2	F-2
S-3	M-3	F-3

E

Replacement

E says, "Now I am going to take away one block and I want you to put it back so that the board looks just the same as it does right now." E then removes S-1, puts it on the table near the Ss left hand, and says, "Now you put this block back where it belongs." When S has finished, E says, "Now I am going to take away two blocks and I want you to put them back so the board looks just the same as it does right now." E then

removes F-1 and M-2, places them in front of S, and says, "Now you put these back where they belong." When S has finished, E says, "Now I am going to take away three blocks and I want you to put them back so the board looks just the same as it does right now." E then removes F-3, M-2, and S-1, places them in front of S, and says, "Now you put these back where they belong."

Reproduction

E says, "This time I am going to take all of the blocks off the board and I want you to put them back so the board looks just the same as it does right now. Look at the board very carefully so you can remember just what it looks like." When S has finished looking, E removes (unsystematically) the nine blocks, mixes them on the table, and says, "Now I want you to put the blocks back so that the board looks just the same as it did before."

Transposition

E says, "This time I am going to take all of the blocks off the board again. Then I am going to put one back, but it will be in a different place. I want you to put the blocks back so they make a pattern like this one. Now look at the board again very carefully so you can remember just what it looks like." When S has finished looking, E removes (unsystematically) the nine blocks, mixes them on the table, and places the bottom left-hand block (F-1) at the top left-hand corner. E then says, "Now you put all these blocks back on the board so they make a pattern like they did before. Remember, this one (pointing at F-1) must stay right here."

Appendix C

ADMINISTRATOR'S MANUAL FOR REVISED CROSS CLASS AND REVISED DOUBLE SERIES MATRIX TASKS

Materials for Revised Blue Cylinder Tasks

9 blue cylinders keyed with the following abbreviations:

S=skinny	1=short
M=medium width	2=medium height
F=fat	3=tall

3 x 3 section wooden board

Materials for Revised Green Square Tasks

9 green squares, corresponding to the same abbreviations as follows:

S=small	1=light green
M-medium size	2=medium green
F=large	3=dark green

The same wooden board as for blue cylinders.

Procedure

While the procedure given below is for the blue cylinder tasks, by using the key given above for green squares the same procedure may be applied for the tasks with green squares.

Procedure

E places the nine blocks in a random fashion on the table next to the matrix board and says, "Tell me what you see here."

(a) If S does not mention the differing heights, E points out M3 and M1 and asks, "How are these two blocks different?" If S refers only to the size difference (for instance, "One is big and one is little"), E says, "That's right, one is tall and one is short."

(b) If S does not mention the differing widths, E points out S2 and F2 and asks, "How are these two blocks different?" If S refers only to the size difference (for instance, "One is big and one is little"), E says, "That's right, one is skinny and one is fat."

E then says, "Now I am going to put the blocks on this board in a special way." E unsystematically[1] places the blocks as in Figure A-1.

Figure A-1

S

	(col.1)	(col.2)	(col.3)
(row 1)	M3	S3	F3
(row 2)	M1	S1	F1
(row 3)	M2	S2	F2

E

E says, "Look very carefully at how the blocks go. They make a pattern. Look carefully to see the pattern."

---

[1]This means neither by row nor by column. Instead something like: first S3, then M2, then F3, etc.

After 15 seconds, E removes blocks in Column 1 (M3, M1, M2) and places each block off the board next to its square as in Figure A-2.

Figure A-2

S

M3		S3	F3
M1		S1	F1
M2		S2	F2

E

E moves blocks from Column 3 (F3, F1, F2) to Column 1, then places M3, M1, and M2 in Column 3 so that matrix looks like Figure A-3.

Figure A-3

S

F3	S3	M3
F1	S1	M1
F2	S2	M2

E

E says, "Look carefully at how the blocks now go. They make a pattern now, too. Look carefully to see the pattern."
After 15 seconds, E removes blocks in Row 3 (F2, S2, M2) and places each block off the board next to its square as in Figure A-4.

Figure A-4

S

F3	S3	M3
F1	S1	M1

F2 S2 M2

E

E moves blocks from Row 1 (F3, S3, M3) to Row 3, then places F2, S2, and M2 in Row 1 so that matrix looks like Figure A-5.

Figure A-5

S

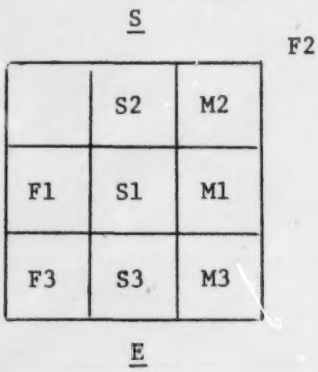
	(col.1)	(col.2)	(col.3)
(row 1)	F2	S2	M2
(row 2)	F1	S1	M1
(row 3)	F3	S3	M3

E

E says, "Look carefully again at how the blocks go. They make a pattern this way, too. Look carefully to see the pattern."

After 15 seconds, E says, "Now I am going to take away one block and then ask you to put it back so that the board looks the same as it does right now." E removes F2, puts it on the table as in Figure A-6.

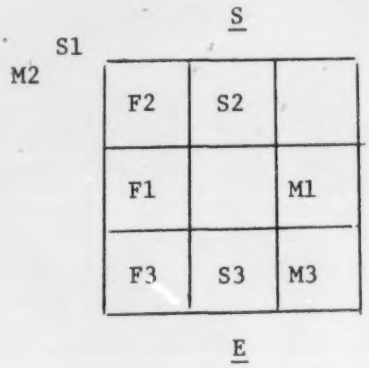
Figure A-6



E says, "Please put this block (E pointing to F2) back where it belongs." E records S's response on scoresheet. If S does not correctly replace F2, E places it back in position.

Next, E says, "Now I am going to take away two blocks and then ask you to put them back so that the board looks the same as it does right now." E removes M2 and S1, and places them as in Figure A-7.

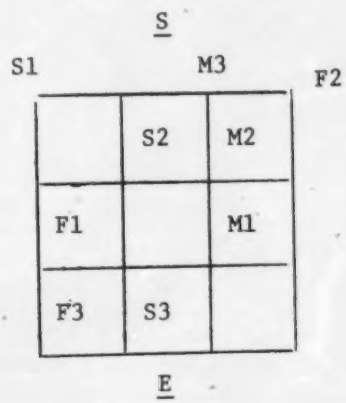
Figure A-7



E says, "Please put these blocks (E pointing to M2 and S1) back where they belong." E records S's response on scoresheet. If S does not correctly replace two blocks, E places them back in position.

Then, E says, "This time I am going to take away three blocks and then ask you to put them back so that the board looks the same as it does right now." E removes S1, F2, and M3 and puts them on table as in Figure A-8.

Figure A-8

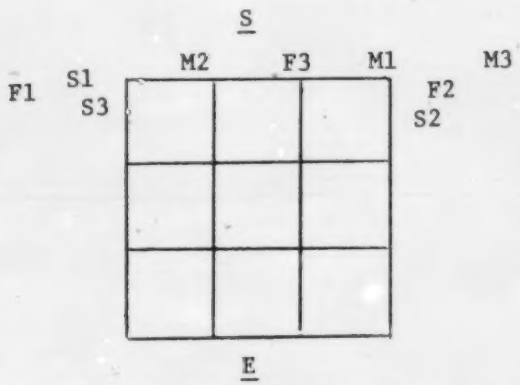


E says, "Please put these blocks (E pointing to S1, M3, and F2) back where they belong." E records S's response on scoresheet. If S does not correctly replace three blocks, E places them back in position.

Next, E says, "This time I am going to take all the blocks off the board. Then I am going to put one back, but it will be in a different place than it is now. After that I will ask you to put the blocks back so that they make a pattern like this one. Now look at the board very carefully so that you can remember the pattern."

After 15 seconds, E removes all the blocks from the board in an unsystematic fashion and places them as in Figure A-9.

Figure A-9



If S is assigned presentation order (1), E places F3 in center position as in Figure A-10-1. If S is assigned presentation order (2), E places M2 in center position as in Figure A-10-2.

Figure A-10-1

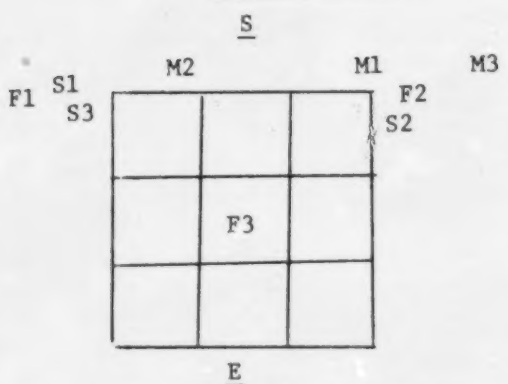
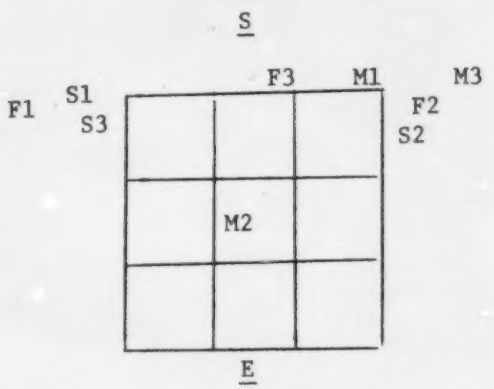


Figure A-10-2

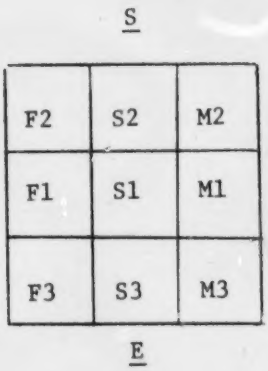


Then E says, "Please put the blocks back on the board so that they make a pattern like they did before. Remember, do not remove this block (E pointing to block in center). It must stay right where it is." If S attempts to lift center block, she/he is reminded that it is to stay in its place. E records S's response on scoresheet.

When S is finished, E assures S that he/she did very well.

E removes all blocks from board and places them as in Figure A-11 below (note: same as Figure A-5).

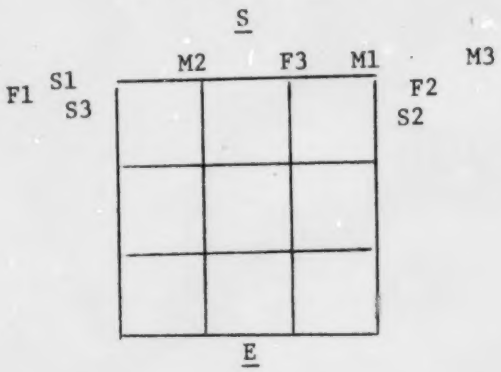
Figure A-11



E says, "This time I am going to take all the blocks off the board. Then I am going to put one back, but it will be in a different place than it is now. After that I will ask you to put the blocks back so that they make a pattern like this one. Now look at the board very carefully so that you can remember the pattern. "

After 15 seconds, E removes all the blocks from the board in an unsystematic fashion and places them as in Figure A-12 (note: same as Figure A-9).

Figure A-12



If S is assigned presentation order (1), E places M2 in center position as in Figure A-13-1. If S is assigned presentation order (2), E places F3 in center position as in Figure A-13-2.

Figure A-13-1

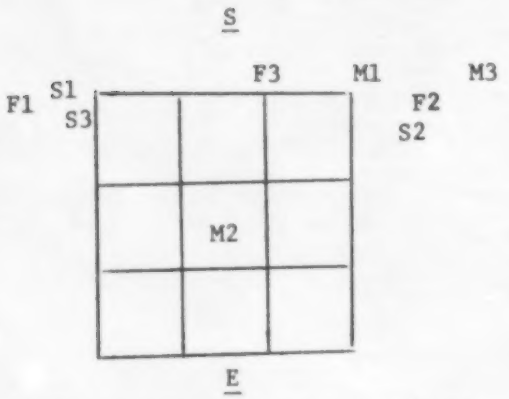
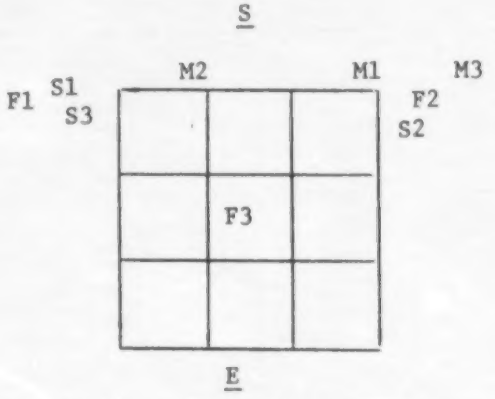


Figure A-13-2



Then E says, "Please put the blocks back on the board so that they make a pattern like they did before. Remember, do not remove this block (E pointing to block in center). It must stay right where it is." If S attempts to lift center block, he/she is reminded that it is to stay in its place. E records S's response on scoresheet.

When S is finished, E assures S that she/he did very well.

General

S is always reassured about her/his performance whether she/he replaces all the objects correctly or not. If at any time S replaces the blocks incorrectly, the blocks are placed correctly by E before proceeding to the next task. However, when this happens E reassures S that he/she is doing well and explains that E is arranging the blocks for the next game. After the warm-up (i.e., after end of Page 43), E never mentions the height or width of any of the blocks.

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9/78